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Use of cover crops as a tool in the management strategy of sourgrass[1]

Uso de plantas de cobertura como ferramenta na estratégia de manejo de capim-amargoso

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Abstract - The use of cover crops with potential to reduce the development of weeds in crops may represent an important tool in an integrated weed management. To do so, work to evaluate initial development of *Digitaria insularis* under cover crops residues on the soil surface was conducted in the 2014/2015 crop in a greenhouse. The experimental design was in randomized blocks in a (7x4) + 1 factorial arrangement, and the factors consisted in seven species of cover crops (*Pennisetum glaucum*, *Crotalaria spectabilis*, *Fagopyrum tataricum*, *Urochloa brizantha* cv. Piatã, *Cajanus cajan*, *Eleusine coracana* and *Mucuna pruriens*) and four levels of dry phytomass (4, 8, 12 and 16 Mg ha^{-1}) plus the control treatment without cover crops, with four repetitions. *M. pruriens*, *C. cajan* e *U. brizantha* stood out in the suppression of *D. insularis*, and 4 Mg ha^{-1} of dry phytomass of these species were sufficient to promote an expressive reduction in the total number of plants emerged, germination speed index, dry phytomass of the shoots, leaf area, dry phytomass and root volume. For these species, from 8 Mg ha^{-1} of phytomass development of *D. insularis* was no longer detected. As for the other species, the control of *D. insularis* was efficient only with high amounts of phytomass (16 Mg ha^{-1}). *D. insularis* was highly sensitive to the presence of residues on the soil surface, making cover crops cultivation an important tool for the integrated management of this species.
Keywords: allelopathy; *Digitaria insularis*; mulch; weeds; resistance

Resumo - O uso de espécies de cobertura com potencial para reduzir o desenvolvimento de plantas daninhas em lavouras podem representar importante ferramenta no manejo integrado de plantas daninhas. Para tanto, conduziu-se na safra 2014/2015 em casa de vegetação um trabalho objetivando avaliar desenvolvimento inicial de *Digitaria insularis* sob resíduos de plantas de cobertura na superfície do solo. O delineamento experimental foi em blocos casualizados em esquema fatorial (7x4) + 1, sendo os fatores constituídos por sete espécies de plantas de cobertura (*Pennisetum glaucum*, *Crotalaria spectabilis*, *Fagopyrum tataricum*, *Urochloa brizantha* cv. Piatã, *Cajanus cajan*, *Eleusine coracana* e *Mucuna pruriens*) e quatro níveis de fitomassa seca (4, 8, 12 e 16 Mg ha^{-1}), mais o tratamento controle sem plantas de cobertura, com quatro repetições. *M.*

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pruriens, *C. cajan* e *U. brizantha* se destacaram na supressão de *D. insularis*, sendo que 4 Mg ha^{-1} de fitomassa seca dessas espécies foram suficientes para promover redução expressiva no número total de plantas emergidas, índice de velocidade de germinação, fitomassa seca da parte aérea, área foliar, fitomassa seca e volume de raízes. Para essas espécies, a partir de 8 Mg ha^{-1} de fitomassa não mais se detectou desenvolvimento de *D. insularis*. Já, para as demais espécies o controle de *D. insularis* foi eficiente apenas com elevadas quantidades de fitomassa (16 Mg ha^{-1}). *D. insularis* se mostrou altamente sensível à presença de resíduos na superfície do solo, tornando o cultivo de plantas de cobertura uma importante ferramenta para o manejo integrado dessa espécie.
Palavras-chaves: alelopatia; *Digitaria insularis*; cobertura morta; plantas daninhas; resistência

Introduction

From the release on a commercial scale of glyphosate-tolerant soybean cultivars planting, technology Roundup Ready® (RR®), the usage intensity of this herbicide in agriculture has become even greater due to the possibility of crops postemergence applications, in addition to desiccation on pre-planting (Petter et al., 2007).

With the recent release of RR® maize and cotton cultivars, the use of this herbicide has intensified even more, especially in regions where farming is predominantly in succession with soybeans during the harvest (spring-summer) and maize or cotton in the period of late harvest (fall-winter) (Petter et al., 2015).

However, the continued use of glyphosate in cultivation in succession of RR® crops may favor the selection of glyphosate-tolerant and/or resistant weed biotypes. According to the Associação Brasileira de Ação à Resistência de Plantas Daninhas a Herbicidas (Herbicide Resistance Action Committee; HRAC, 2015), so far in Brazil seven species of weeds resistant to this herbicide were recorded. Among these species, sourgrass (*Digitaria insularis*) is noteworthy for being a perennial species, difficult to control, which has high initial vegetative development, high reproductive capacity and is not restricted to seeds, but also the rhizomes (Lorenzi, 2008).

The control of sourgrass plants after the formation of rhizomes is even more difficult due to the presence of starch in the rhizomes, which hinders the translocation of glyphosate, allowing rapid regrowth of the plants after being treated with this herbicide and their control should preferably be carried out in the early stage of plant development (Machado et al., 2006).

The occurrence of glyphosate-resistant weeds has required the use of alternative management strategies to minimize losses in crops and thus reduce production costs. However, as a main alternative, the use of glyphosate associated with other mechanisms of action has also been adopted as a strategy. However, this should not be the only tool to be used in production systems.

The use of cover crops can be part of the management system to control weeds and also contribute to the maintenance of mulch on the soil, which is a basic premise for NTS (no-tillage system) (Silva et al., 2015). Thus, the production of dry matter and soil cover provided by cover crops are factors that can help control weeds by physical and chemical processes (allelopathy) (Monquero et al., 2009; Pacheco et al., 2013). And the suppressive effect of these on the germination and development of weeds depends on the species, quantity and distribution of residues (Chauhan et al., 2012).

Thus, chemical management associated with culture management with cover crops may be a promising strategy for sourgrass management. However, there is limited information in the literature about the direct effects of cover crops in their early development. Thus, studies on this important issue for the development of sustainable management strategies to control this weed species are needed. To this end, work was conducted to evaluate the effect of stubble from different cover crops on the development and control of *Digitaria insularis*.

Material and Methods

The experiment was conducted in the 2014/2015 crop in a greenhouse in the Brazilian city of Sinop, Mato Grosso. *Digitaria insularis* seeds were collected in areas of rural producers in the region.

The experimental design was in randomized blocks in a (7x4)+1 factorial arrangement, and the factors consisted in seven cover crops [millet (*Pennisetum glaucum*), rattlepod (*Crotalaria spectabilis*), tartary buckwheat (*Fagopyrum tataricum*), brachiaria cv. Piatã (palisade grass) (*Urochloa brizantha*), pigeon pea (*Cajanus cajan (L.) Millsp.*), Indian goosegrass (*Eleusine coracana* (L.) Gaertn.) and velvet bean (*Mucuna pruriens*)] and four levels of dry phytomass on the soil surface (4, 8, 12 and 16 Mg ha^{-1}) plus the control treatment without cover crops, with four repetitions.

For the substrate, soil samples were collected from the 40 – 60 cm layers of dystrophic red latosol and placed in polypropylene pots with a capacity of 8 dm^3 and a diameter of 35 cm. The depth of soil collection (40-60 cm layer) was selected to avoid the interference from theweed seed bank present in the upper soil layers. The soil was prepared to reach the saturation by bases of 50% and fertilized with the formula NPK, at a rate of 0.3 g dm^{-1} of soil, corresponding to 600 kg ha^{-1} of NPK (04:30:15).

Twenty seeds of *Digitaria insularis* were sown in the plots (in each pot) and embedded to a depth of 1 cm. Later, soon after felling in the field, in order to avoid possible loss of allelochemicals, the fresh vegetation cover of the cover crops was segmented into sections of about 4.0 to 5.0 centimeters and added to the soil surface in an amount proportional to the dry phytomass levels (0, 4, 8, 12 and 16 Mg ha^{-1}), which corresponded on average to 0; 19.6; 39.2; 58.8 and 78.4 g pot^{-1} respectively.

For the production of fresh phytomass of the cover crops, plots were installed in the field measuring 4 m by 8 m (32 m^2). At the point of maximum accumulation of dry matter, these species were cut and to calculate the corresponding values of fresh and dry phytomass, samples of fresh residues of each species were dried in a forced-air circulation oven at 60 °C to obtain the constant weight.

Irrigation was performed when necessary, keeping the moisture content around 70% of field capacity. Therefore, additional pots containing the corresponding amounts of phytomass in pots with water were saturated, remaining undisturbed for 12 hours to drain the excess water and determine the mass (field capacity). Then, the mass of the pots was daily monitored to check which corresponded to 70% of the initial weight. By means of the mass difference calculated from the pot in the state of field capacity and the current mass of the pot, the amount of water was added for each treatment.

The Emergence Speed Index (ESI) and the total number of plants emerged (TNPE) were daily evaluated. ESI was calculated using the equation described by Maguire (1962): ESI = [N1 / 1 + (N2-N1) / 2 + (N3– N2) / 3 + ... (Nn, Nn-1) / n], with N1, N2, N3 ... Nn corresponding to the number of seedlings that emerged and 1, 2, 3 ... n with the number of days after sowing (DAS).

At 50 days after sowing (DAS) the dry phytomass of the shoots (DPS), leaf area (LA), dry phytomass of roots (DPR) and root volume (RV) were evaluated. The leaf area was determined with the help of equipment LI-3100 Area Meter (LI-COR Inc. Lincoln, NE, EUA), and the values were presented in cm^2 pot^{-1}. To determine DPS, the sourgrass plants were cut close to the ground and taken to a greenhouse at 60 ºC until reaching a constant weight. The roots were washed and after draining the excess water the roots were placed in a 1 L graduated cylinder containing a standard amount of water of 300 mL. RV was calculated by the difference of volume of water displaced in the graduated cylinder after immersing the roots and the values presented in cm^3 pot^{-1}. After this procedure to obtain the dry phytomass the roots were taken to the greenhouse at 60 ºC until reaching a constant weight.

At first, additivity of the model, normality of errors and homogeneity of variances tests were carried out. Since there was no restriction to the assumptions of analysis of variance, the means of qualitative factors were grouped by the Scott-Knott test ($p < 0.05$) using the statistical program Sisvar (Ferreira, 2011). The quantitative factors were submitted to regression analysis using software SigmaPlot.

Results and Discussion

There was a significant effect of the cover crops species in the Emergence Speed Index (ESI) and in the total number of plants emerged (TNPE) of *D. insularis*, and the largest reductions in the values of these parameters were observed in the stubble cultivation of *Cajanus cajan* and *Mucuna pruriens* and with intermediate values for *U. brizantha* cv. Piatã. From 8 Mg ha^{-1} there is no longer a significant difference among the cover crops species for ESI and TNPE (Table 1 and Figure 1).

Table 1. Emergence Speed Index (ESI) and total number of plants emerged (TNPE) of sourgrass (*Digitaria insularis*) due to the amounts of cover crops biomass deposited on the soil surface (Sinop, MT, 2015).

Cover crops	Amount of biomass (Mg ha^{-1})				
	0	4	8	12	16
	Emergence speed index				
Fagopyrum tataricum	1.66 a	0.73 c	0.11 a	0.02 a	0.02 a
Crotalaria spectabilis	1.66 a	0.53 c	0.13 a	0.05 a	0.00 a
Pennisetum glaucum	1.66 a	0.63 c	0.26 a	0.25 a	0.00 a
Eleusine coracana	1.66 a	0.74 c	0.10 a	0.02 a	0.02 a
Cajanus cajan	1.66 a	0.02 a	0.00 a	0.00 a	0.00 a
U. brizantha cv. Piatã	1.66 a	0.30 b	0.00 a	0.00 a	0.00 a
Mucuna pruriens	1.66 a	0.02 a	0.00 a	0.00 a	0.00 a
CV (%)	9.74				
	Number of plants emerged pot^{-1}				
Fagopyrum tataricum	9.80 a	5.33 c	1.33 a	0.66 a	0.66 a
Crotalaria spectabilis	9.80 a	4.00 c	0.66 a	1.00 a	0.00 a
Pennisetum glaucum	9.80 a	4.66 c	1.66 a	2.33 b	0.00 a
Eleusine coracana	9.80 a	6.33 c	1.00 a	0.33 a	0.33 a
Cajanus cajan	9.80 a	0.33 a	0.00 a	0.00 a	0.00 a
U. brizantha cv. Piatã	9.80 a	2.66 b	0.00 a	0.00 a	0.00 a
Mucuna pruriens	9.80 a	0.33 a	0.00 a	0.00 a	0.00 a
CV (%)	22.63				

Means followed by the same letter in the column do not differ by the Scott-Knott test ($p \geq 0.05$).

The exponential model of adjustment to the data shows a marked effect on ESI and TNPE, even in amounts of stubble on the soil surface below 4 Mg ha^{-1}. Significant reductions in the development of *Digitaria* spp. were also observed with cover of 6.0 Mg ha^{-1} of ryegrass stubble on the soil surface (Moraes et al., 2011). These results show the high sensitivity of *D. insularis* to the presence of cover crops residues on the soil surface. This sensitivity is related primarily to the photoblastic mechanism of *D. insularis*, which was sensitive to the reduction of light and the possible chemical (allelopathic) effect resulting from the decomposition of cover crops.

Although Klein and Felippe (1991) report this species as neutral photoblastic, in recent work by Mendonça et al. (2014) it was proved that it is a positive photoblastic species. Therefore, the physical barrier provided by the cover crops reduced the quality and quantity of light required to stimulate the germination process of *D. insularis*, reducing the number of plants emerged. As for the chemical effect, it may have acted by inhibiting the germination mechanism due to the release of phenolic compounds. The most pronounced effect of the stubble *of C. cajan* and *M. pruriens* may be related to the higher speed of release of phenolic compounds from the low C/N ratio and rapid decomposition of residues.

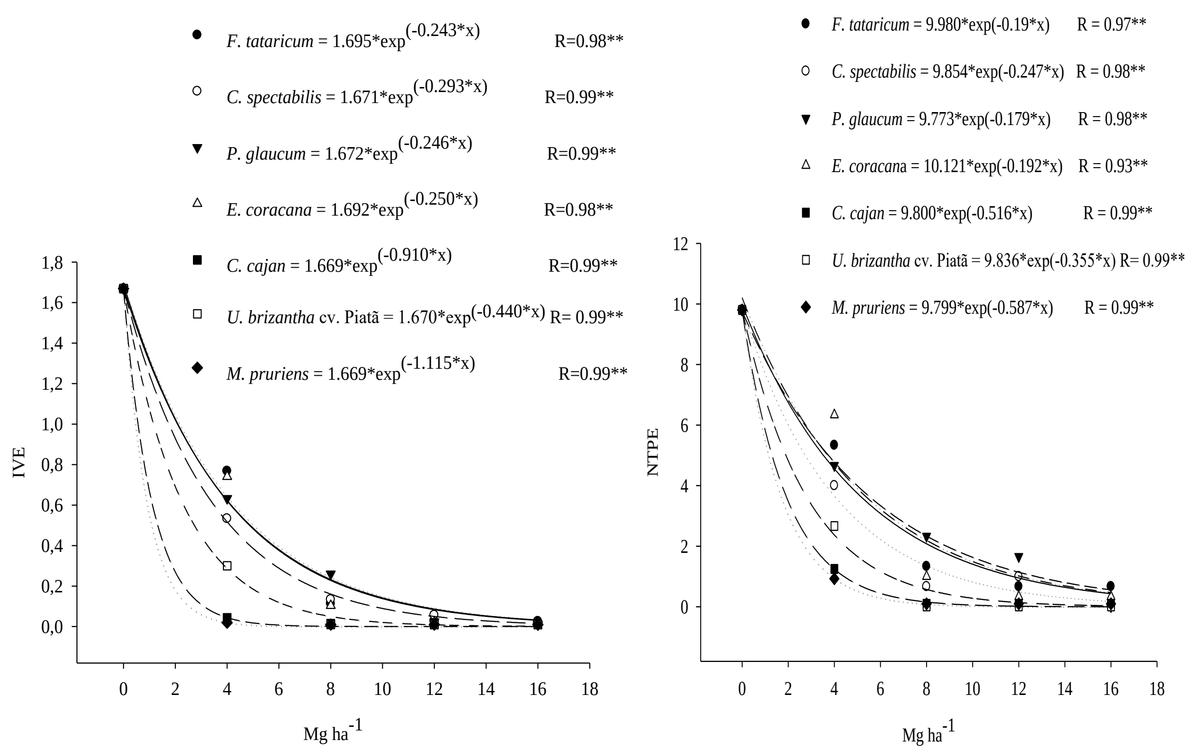

Figure 1. Emergence Speed Index (ESI) and total number of plants emerged per pot (TNPE) of *Digitaria insularis* under cover crops stubble levels deposited on the soil surface. ** Significant at 1% of probability by the F-test.

Physical and allelopathic effects of cover crops on the early development of weeds were reported by Sodré Filho et al. (2008) and Pacheco et al. (2013a). ESI delay is an important aspect in the management of *D. insularis* as it provides greater crop competitiveness in the early development and hence it boosts the effectiveness of chemical management through the application of herbicides at earlier stages of development of this species.

The dry phytomass of the shoots (DPS) and leaf area (LA) were influenced ($p < 0.05$) by residues of cover crops on the soil surface (Table 2 and Figure 2). The largest reductions of DPS and LA were observed in treatments with *C. cajan* and *M. pruriens*, and this effect was superior to other treatments and with only 4 Mg ha^{-1} of phytomass on the soil surface. The reductions of DPS and LA were of 94% and 95% for *C. cajan* and of 93% and 92% for *M. pruriens* respectively. As from 8 Mg ha^{-1} of dry phytomass of *C. cajan*, *M. pruriens* and *U. brizantha* cv. Piatã on the soil surface promoted total control of *D. insularis* plants. Gimenes et al. (2011) have observed control of 93% of *C. echinatus* and 80% of reduction of leaf area of *D. horizontalis* with the presence of 10 Mg ha^{-1} of dry phytomass of *U. decumbens*.

Overall, considering these parameters, the other species only had levels of efficiency above 85% in the control of *D. insularis* from 16 Mg ha^{-1}. However, amounts close to 10 Mg ha^{-1} are already sufficient to reduce DPS of *D. insularis* in over 50% and therefore can contribute to higher efficiency of the chemical management.

Table 2. Dry phytomass of the shoots and leaf area of sourgrass plants according to the amount of biomass of cover crops deposited on the soil surface (Sinop, MT, 2015).

Cover crops	Amount of phytomass (Mg ha^{-1})				
	0	4	8	12	16
	Dry phytomass of the shoots (g pot^{-1})				
Fagopyrum tataricum	7.95 a	7.73 b	6.93 b	4.13 b	2.16 a
Crotalaria spectabilis	7.95 a	5.96 b	3.23 a	2.23 b	0.10 a
Pennisetum glaucum	7.95 a	6.93 b	4.56 b	3.53 b	0.10 a
Eleusine coracana	7.95 a	6.70 b	3.86 b	1.90 a	1.16 a
Cajanus cajan	7.95 a	0.50 a	0.00 a	0.00 a	0.00 a
U. brizantha cv. Piatã	7.95 a	4.86 b	0.00 a	0.00 a	0.00 a
Mucuna pruriens	7.95 a	0.53 a	0.00 a	0.00 a	0.00 a
CV (%)	16.41				
	Leaf area (cm^2 pot^{-1})				
Fagopyrum tataricum	293.7 a	211.8 b	198.7 c	136.2 c	38.4 a
Crotalaria spectabilis	293.7 a	134.8 b	66.6 b	45.2 c	1.00 a
Pennisetum glaucum	293.7 a	252.3 b	184.2 c	118.2 b	48.2 a
Eleusine coracana	293.7 a	169.9 b	32.2 a	10.7 a	7.29 a
Cajanus cajan	293.7 a	15.9 a	0.00 a	0.00 a	0.00 a
U. brizantha cv. Piatã	293.7 a	168.0 b	0.00 a	0.00 a	0.00 a
Mucuna pruriens	293.7 a	25.9 a	0.00 a	0.00 a	0.00 a
CV (%)	16.76				

Means followed by the same letter in the column do not differ by the Scott-Knott test ($p \geq 0.05$).

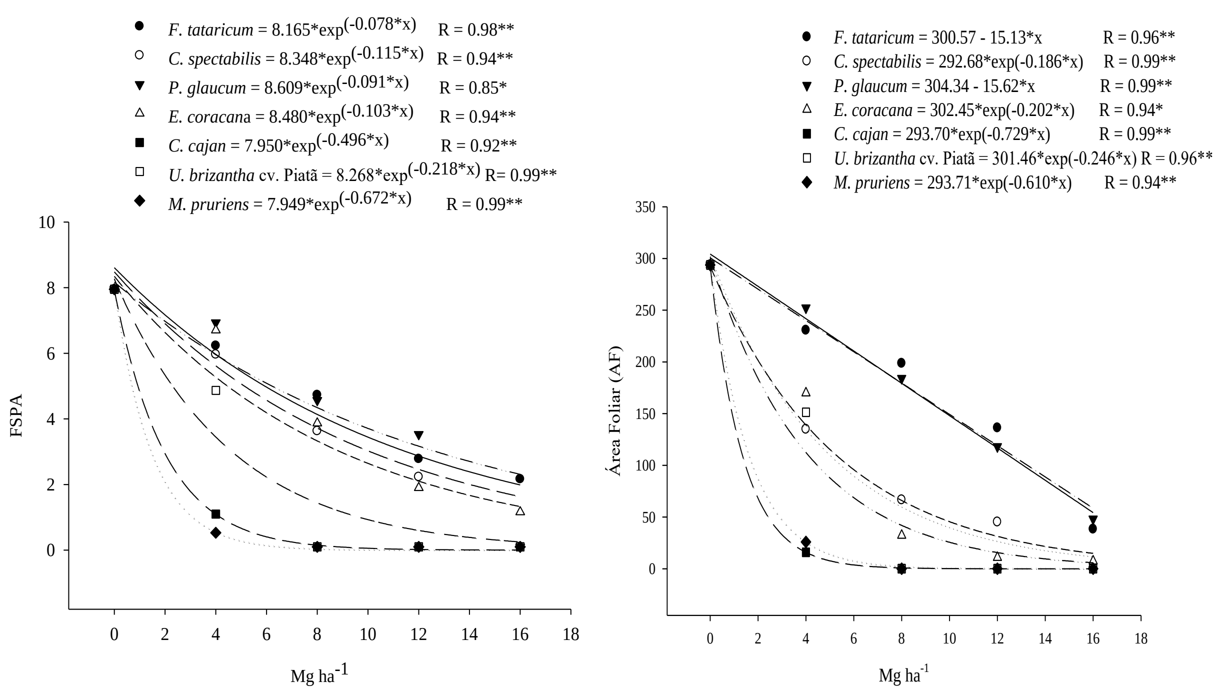

Figure 2. Dry phytomass of the shoots (DPS) and leaf area (LA) per pot of *Digitaria insularis* under cover crop stubble levels deposited on the soil surface. ** e * Significant at 1% and 5% of probability by the F-test.

Similar to the results for DPS, dry phytomass of roots (DPR) and root volume (RV) of *D. insularis* were also influenced by the cover crops residues, again highlighting *C. cajan* and *M. Pruriens,* which with 4 Mg ha^{-1} of phytomass on the soil surface were sufficient to reduce in 96% and 92% the values of DPR and RV respectively (Table 3 and Figure 3). As for DPS, from 8 Mg ha^{-1} of dry phytomass of *C. cajan*, *M. pruriens* and *U. brizantha* cv. Piatã on the soil surface, DPR and RV of the *D. insularis* plants were no longer observed. Reduction over 50% of DPR and RF of weeds *Bidens pilosa* and *C. echinatus* as usage of cover crops were also observed by Pacheco et al. (2013a) and Silva et al. (2015).

Table 3. Dry phytomass of the root and root volume of sourgrass plants according to the amount of biomass of cover crops deposited on the soil surface (Sinop, MT, 2015).

Cover crops	Amount of dry phytomass of the root (Mg ha^{-1})				
	0	4	8	12	16
	Dry phytomass of the root (g pot^{-1})				
Fagopyrum tataricum	6.50 a	5.36 b	6.13 c	3.63 b	1.63 a
Crotalaria spectabilis	6.50 a	4.95 b	3.80 b	2.66 b	0.00 a
Pennisetum glaucum	6.50 a	5.42 b	4.53 b	3.20 b	0.00 a
Eleusine coracana	6.50 a	5.16 b	3.20 b	1.53 a	1.60 a
Cajanus cajan	6.50 a	0.40 a	0.00 a	0.00 a	0.00 a
B. brizanta cv. Piatã	6.50 a	3.66 a	0.00 a	0.00 a	0.00 a
Mucuna pruriens	6.50 a	0.46 a	0.00 a	0.00 a	0.00 a
CV (%)			16.10		
	Root volume (cm^3 pot^{-1})				
Fagopyrum tataricum	13.7 a	11.66 b	9.66 c	6.33 b	1.66 a
Crotalaria spectabilis	13.7 a	13.33 b	3.33 a	2.33 a	0.00 a
Pennisetum glaucum	13.7 a	11.66 b	5.00 b	2.33 b	0.00 a
Eleusine coracana	13.7 a	13.33 b	3.33 a	1.66 a	1.66 a
Cajanus cajan	13.7 a	0.66 a	0.00 a	0.00 a	0.00 a
B. brizanta cv. Piatã	13.7 a	6.66 b	0.00 a	0.00 a	0.00 a
Mucuna pruriens	13.7 a	0.66 a	0.00 a	0.00 a	0.00 a
CV (%)			21.95		

Means followed by the same letter in the column do not differ by the Scott-Knott test ($p \geq 0.05$).

Effects on DPR and RV due to cover crops are possibly related to the reduction in the competitiveness of *D. insularis* in the absorption of water and soil nutrients. This inhibition of competitiveness may be related to the release of compounds with allelopathic activity such as phenols and flavonoids that act by inhibiting enzymatic and microorganism activity (Andrade et al., 2007; Silva et al., 2015).

The exponential behavior of the data reveals the high efficiency of residues of *C. Cajan*, *M. Prurien* and *U. brizantha*, even in amounts considered relatively low for residues of cover crops, since these species have high potential for phytomass production. Pacheco et al. (2013b), Petter et al. (2013) and Lima et al. (2015) have observed a dry phytomass yield of *C. Cajan*, *M. pruriens* and *U. brizantha* higher than 8 Mg ha^{-1} in cerrado conditions, respectively. Therefore, in the specific case of *D. insularis*, because it is a species with capacity for being perennial and that presents a reproduction mechanism also via vegetative part (rhizomes) (Lorenzi, 2008) the reduction of DPR and RF results in lower reproductive capacity and competition with cultivated plants.

The contribution of cover crops as a management strategy of *D. insularis* is evident, contributing to ESI delay, TNPE reduction and morphological and physiological characteristics DPS, LA, DPR and RV. Another aspect to be considered is the high sensitivity of this species to residues of cover crops species and this sensitivity is expressive even in relatively low amounts of residues deposition. This is important, especially in areas where the production of large amounts of biomass for cover crops is hampered by limited water availability in intercropping, for example, in some areas of the cerrado (Pacheco et al., 2008). Accordingly, for these regions the use of the brachiaria genus species and the mucuna itself are fully viable alternatives due to the high dry phytomass production capacity and tolerance to drought (Petter et al., 2013).

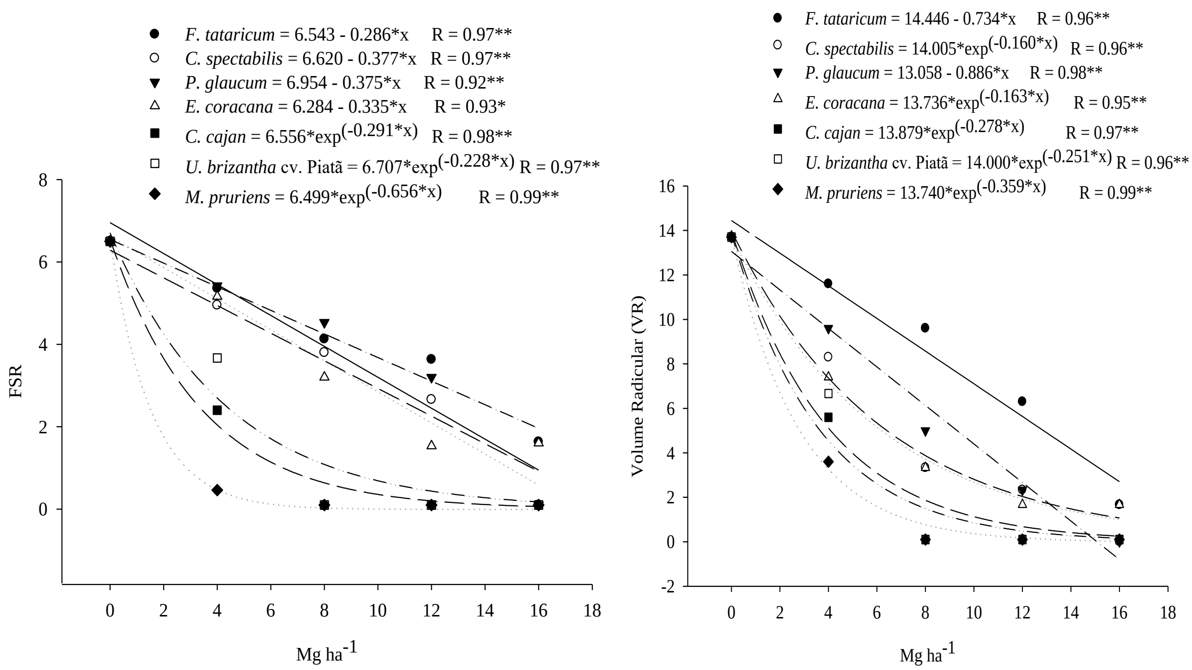

Figure 3. Dry phytomass of roots (DPR) and root volume (RV) per pot of *Digitaria insularis* under cover crop stubble levels deposited on the soil surface. ** e * Significant at 1% and 5% of probability by the F-test.

With the emergence of glyphosate-resistant biotypes of *D. insularis*, recently research has focused on management strategies aimed primarily to the use of herbicides (Pereira et al., 2010; Melo et al., 2012; Barroso et al., 2014) and more recently for rotational management of events with different transgenes for herbicides. However, insertion of a management program which includes the use of herbicides associated to crop management with cover crops is not effected in practice. In this context, this paper presents relevant information to insert cover crops effectively as a management strategy of *D. insularis*, proving the hypothesis proposed for this study. However, the strategy discussed should not be limited only to the use of cover crops, but associating them to chemical control through rotation of herbicide and crop molecules. The combination of chemical and culture controls results in a management system with greater sustainability and mitigation capacity for the emergence of biotypes of *D. insularis* that are tolerant and/or resistant to herbicides.

Conclusions

Cover crops species *M. pruriens*, *C. cajan* and *U. brizantha* stood out in the suppression of *D. insularis*, and 4 Mg ha^{-1} of dry phytomass of these species were sufficient to promote significant reduction in the total number of plants emerged, germination speed index, dry phytomass of shoots, leaf area, dry phytomass and roots volume.

For species *M. pruriens*, *C. cajan* and *U. brizantha*, from 8 Mg ha^{-1} of phytomass development of *D. insularis* was no longer detected. For the other species the control of *D. insularis* was efficient only with high amounts of phytomass (16 Mg ha^{-1}).

Weed species *D. insularis* was highly sensitive to residues on the soil surface, making the cultivation of cover crops an important tool for the integrated management of this species.

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